



Rete dei Laboratori Universitari di Ingegneria Sismica (Reluis)

*Materiali ed Approcci Innovativi per il Progetto in Zona Sismica e la Mitigazione della Vulnerabilità delle Strutture*

*Università degli Studi di Salerno – Consorzio ReLUIS,  
12-13 Febbraio 2007*

***STEEL BUCKLING RESTRAINED BRACES  
FOR SEISMIC UPGRADING  
OF RC BUILDINGS***



**M. D'Aniello, G. Della Corte and F.M. Mazzolani**

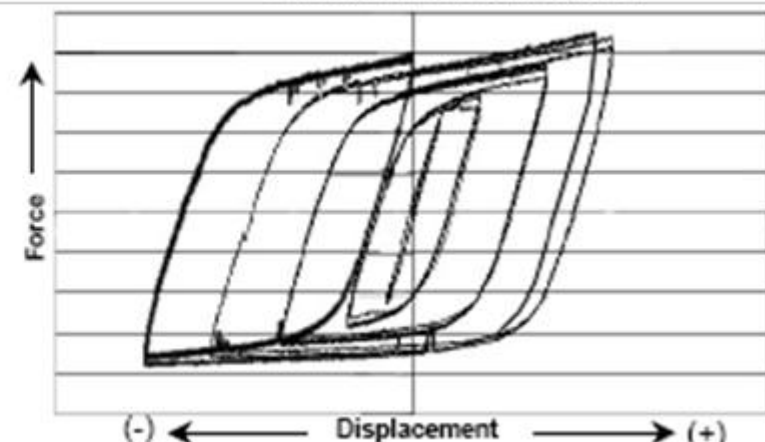
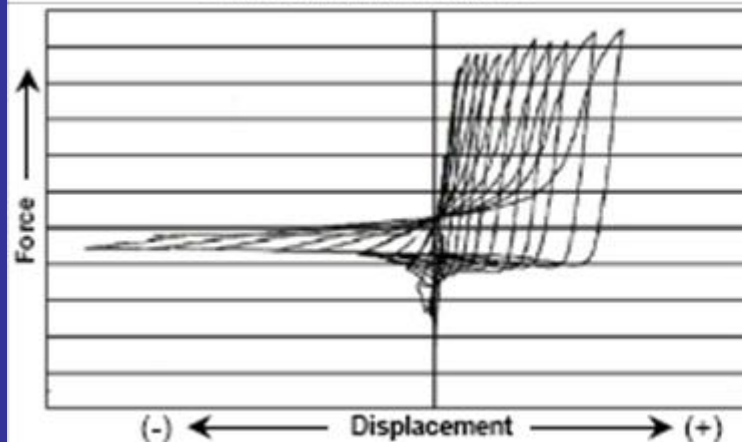
# BUCKLING RESTRAINED BRACES (BRBs)



- Buckled out  
- Poor nonlinear behaviour

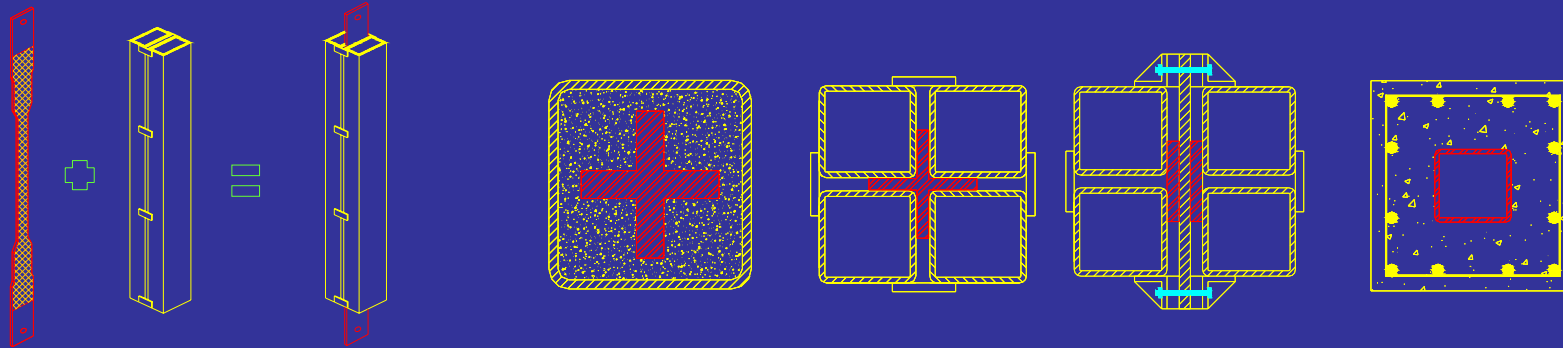


- Unbuckled  
- Excellent nonlinear behaviour



**BRBs provide complete truss action with the same response both in tension and in compression characterized by compact and round hysteresis loops**

# BUCKLING RESTRAINED BRACES (BRBs)



Several types of BRBs have been studied, but two main typologies can be distinguish:

1. Unbonded BRBs
2. Only-steel BRBs.

**“Only-steel” BRBs have some advantages over “unbonded” braces:**

- a. **Only-steel can be designed to be detachable and inspected after each seismic event and, if necessary, the yielded steel core can be replaced by a new one.**
- b. **A detachable BRB allows maintenance during the life-time.**
- c. **Only-steel BRB is lighter than an Unbonded; this implies a technical and economical advantage during the assembling**

# Research objectives

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*These advantages led to study a special only-steel detachable BRB, to be used for improving the seismic response of existing buildings. A wide experimental program has been planned as a first step:*

## ***1. Experimental phase A:***

*Test on a masonry-infilled RC building seismically retrofitted by BRBs*

*1.1 Design of BRB system and “push-pull” test on the retrofitted building*

*1.2 Development and calibration of numerical models*

*1.3 Vulnerability assessment*

## ***2. Experimental phase B:***

*Experimental activity on sub-assembly elements of only-steel BRBs .*

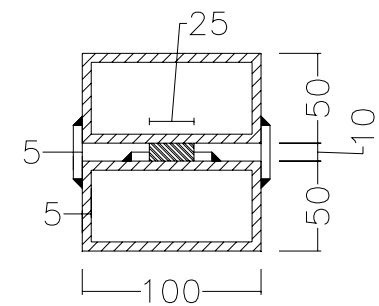
*2.1 Cyclic tests on sub-assembly elements*

*2.2 Calibration and characterization of key properties of a special steel built-up BRBs*

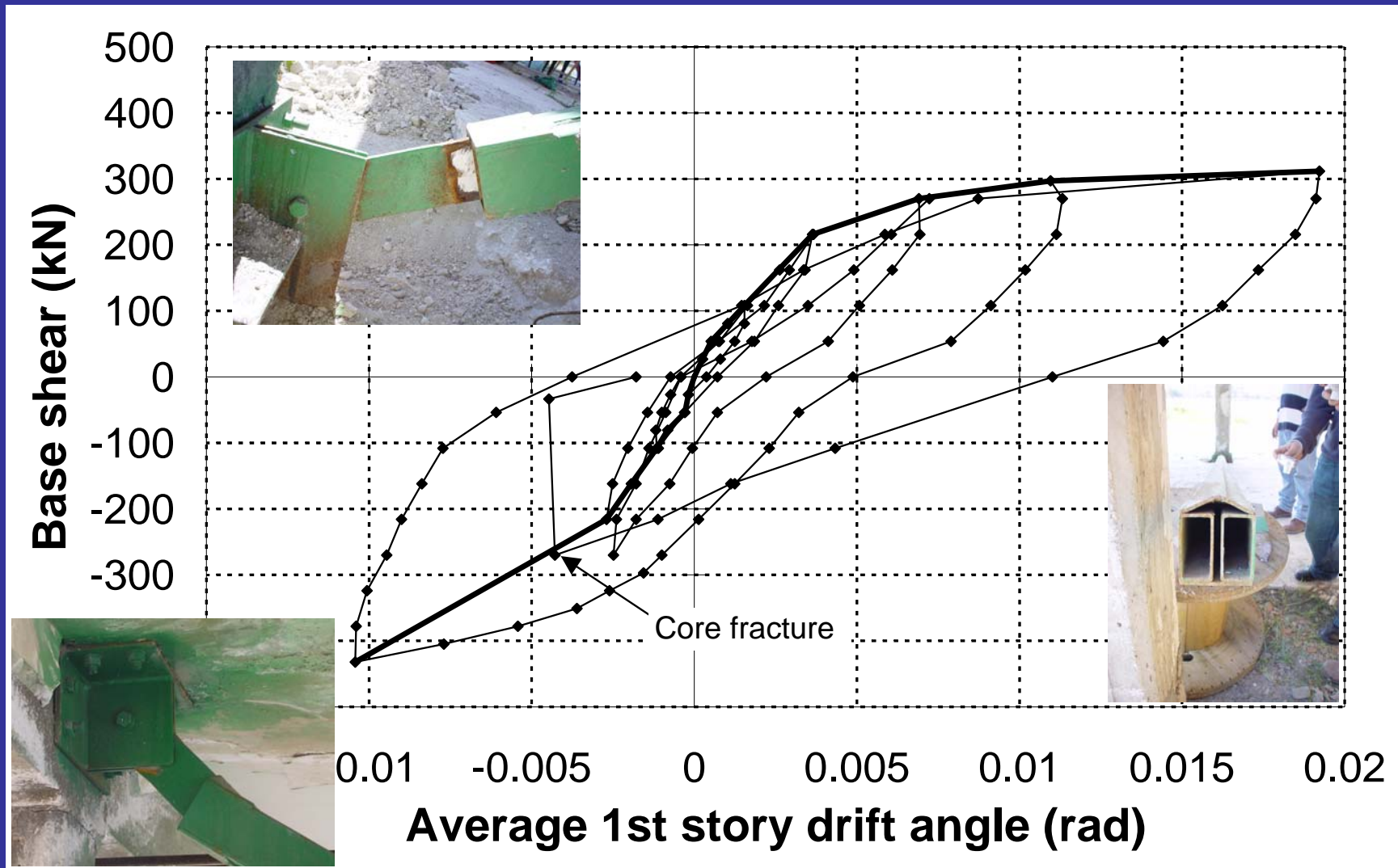
***Experimental phase A:  
Full-scale field tests on  
Buckling Restrained Braces***

Two experimental tests, already performed within the ILVA-IDEM project (Mazzolani 2006), can be considered as the starting point of this experimental study.

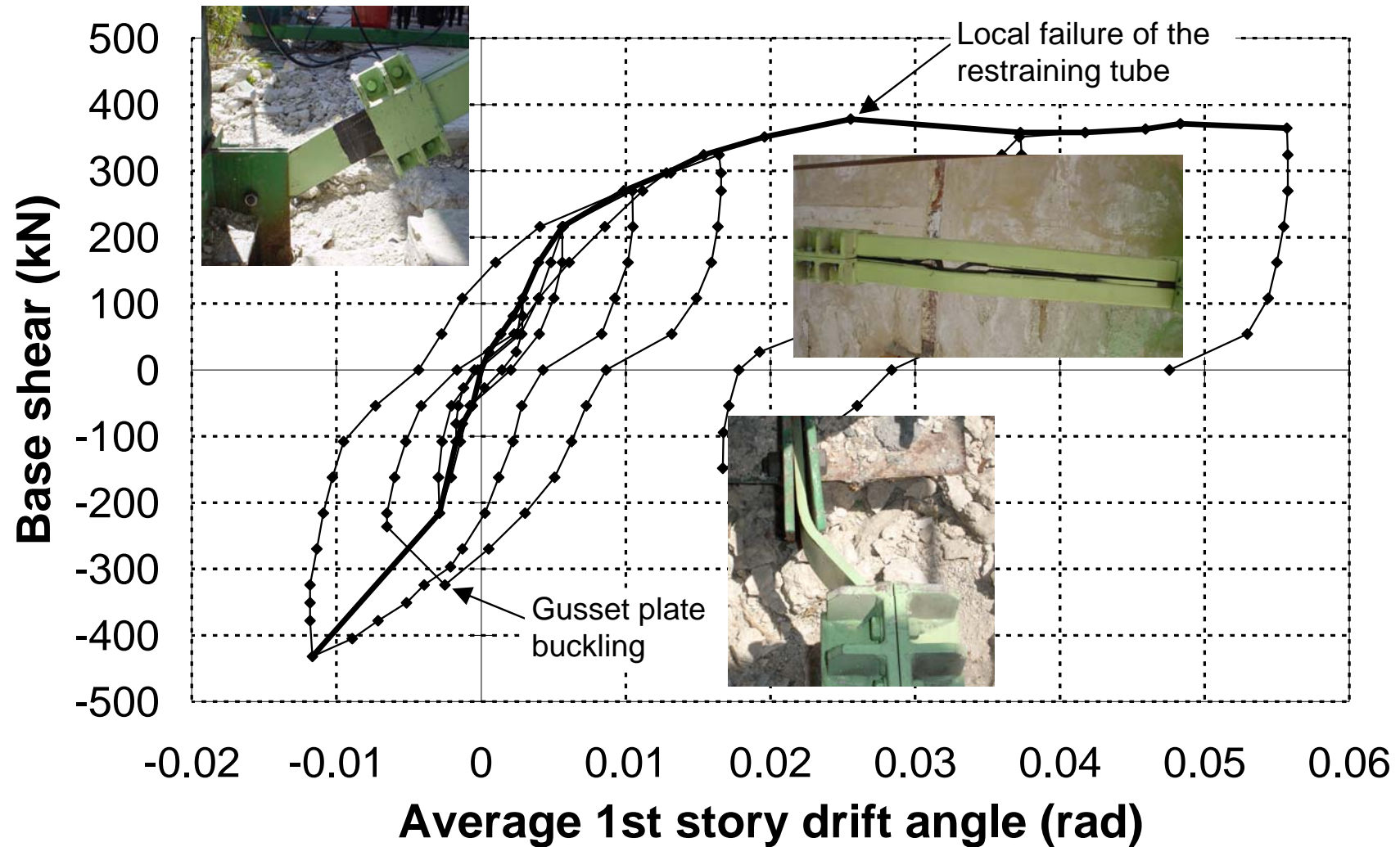
# Scientific Background: Test 1



# Scientific Background: Test 1



# Scientific Background: Test 2



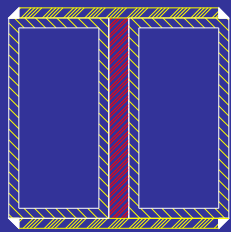
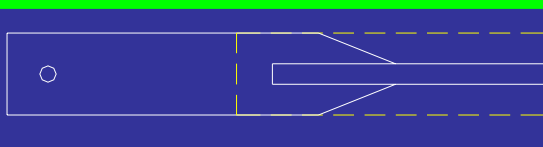


# Scientific Background:

## Comparison between Test 1-Test 2

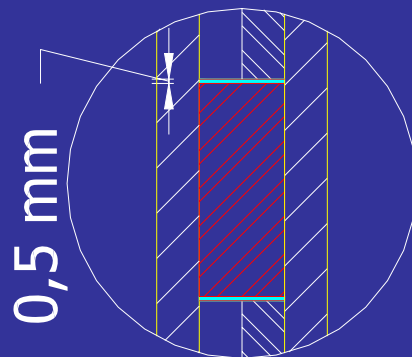
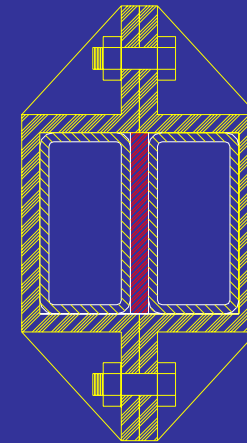
1st type of BRB: Not detachable

2nd type of BRB: Detachable

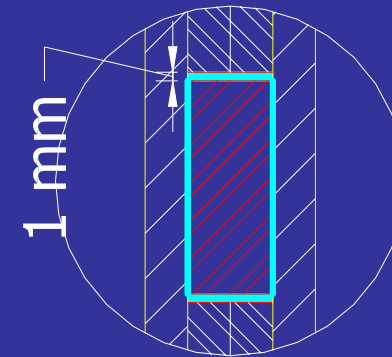


1) the BRB internal core was now tapered in a more gradual manner.

2) the two restraining tubes were now joined together by means of bolted stiffened elements, allowing the BRB to be opened for inspection and monitoring

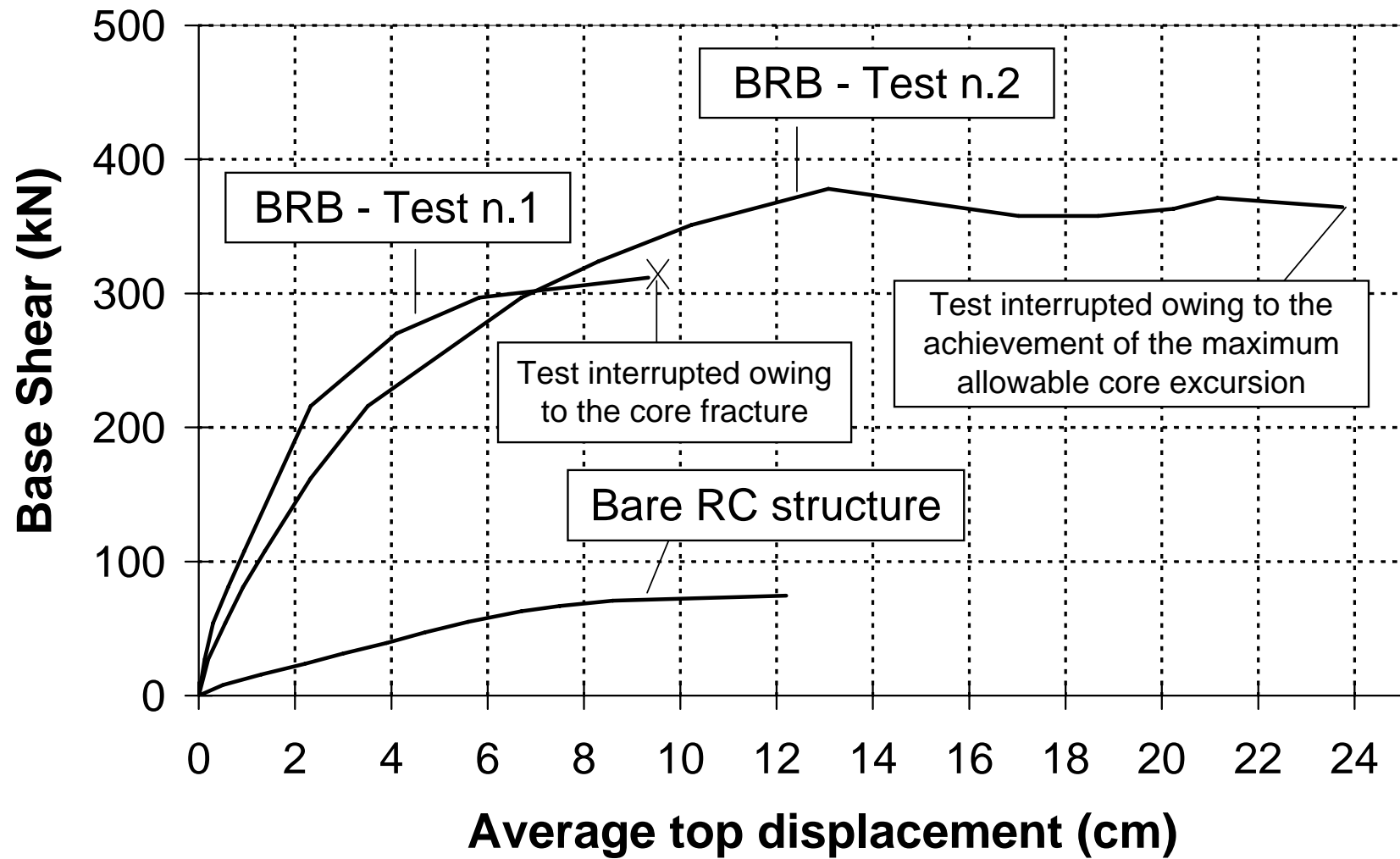


Increase of total clearance with the core and the restraining elements from 1mm (0.5mm for each side) to 2mm (1mm for each side).



# Scientific Background:

## Comparison between Test 1-Test 2



# Masonry-infilled RC building

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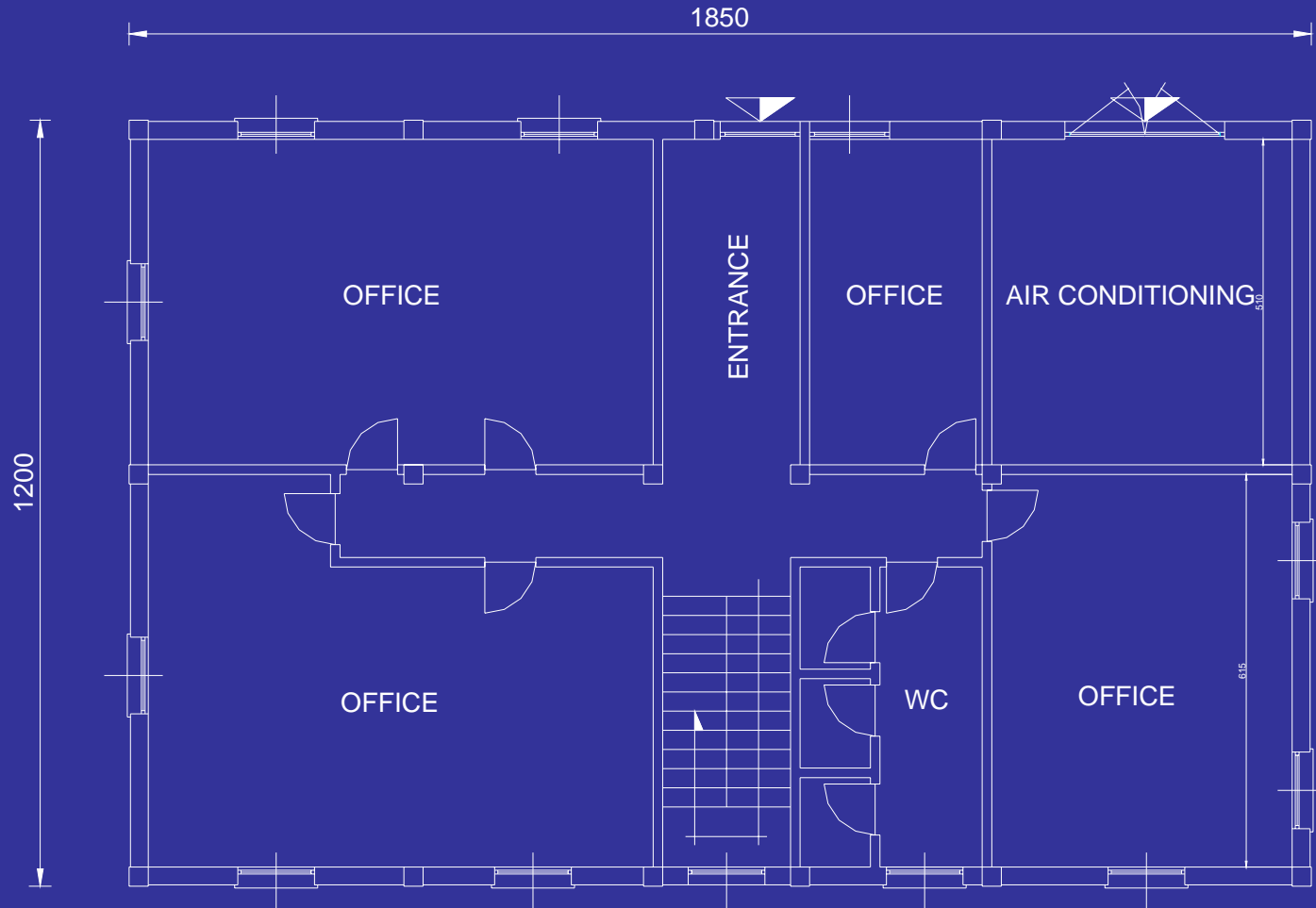
N – W view



S – E view

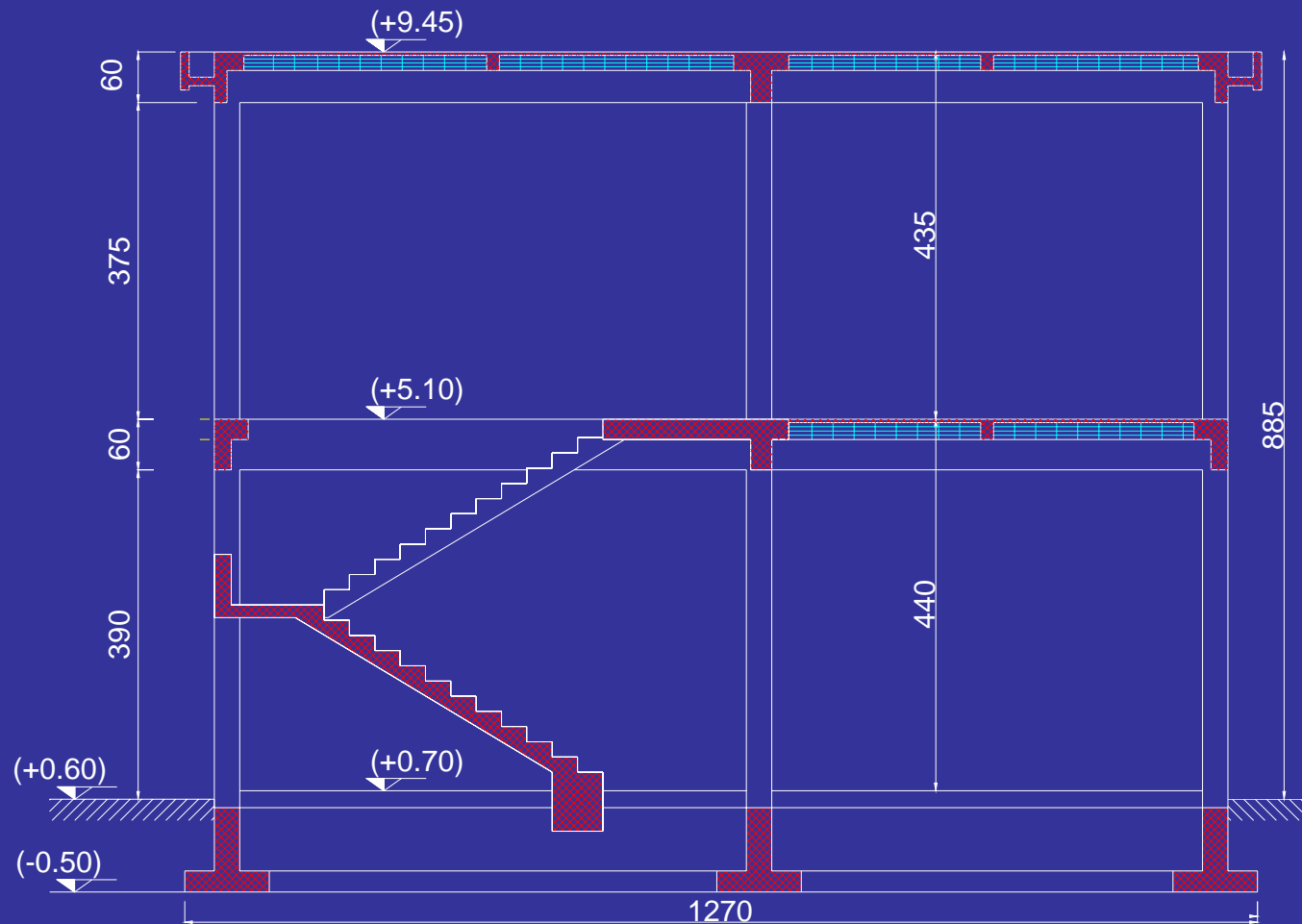
# Masonry-infilled RC building

Ground Floor scale 1:100

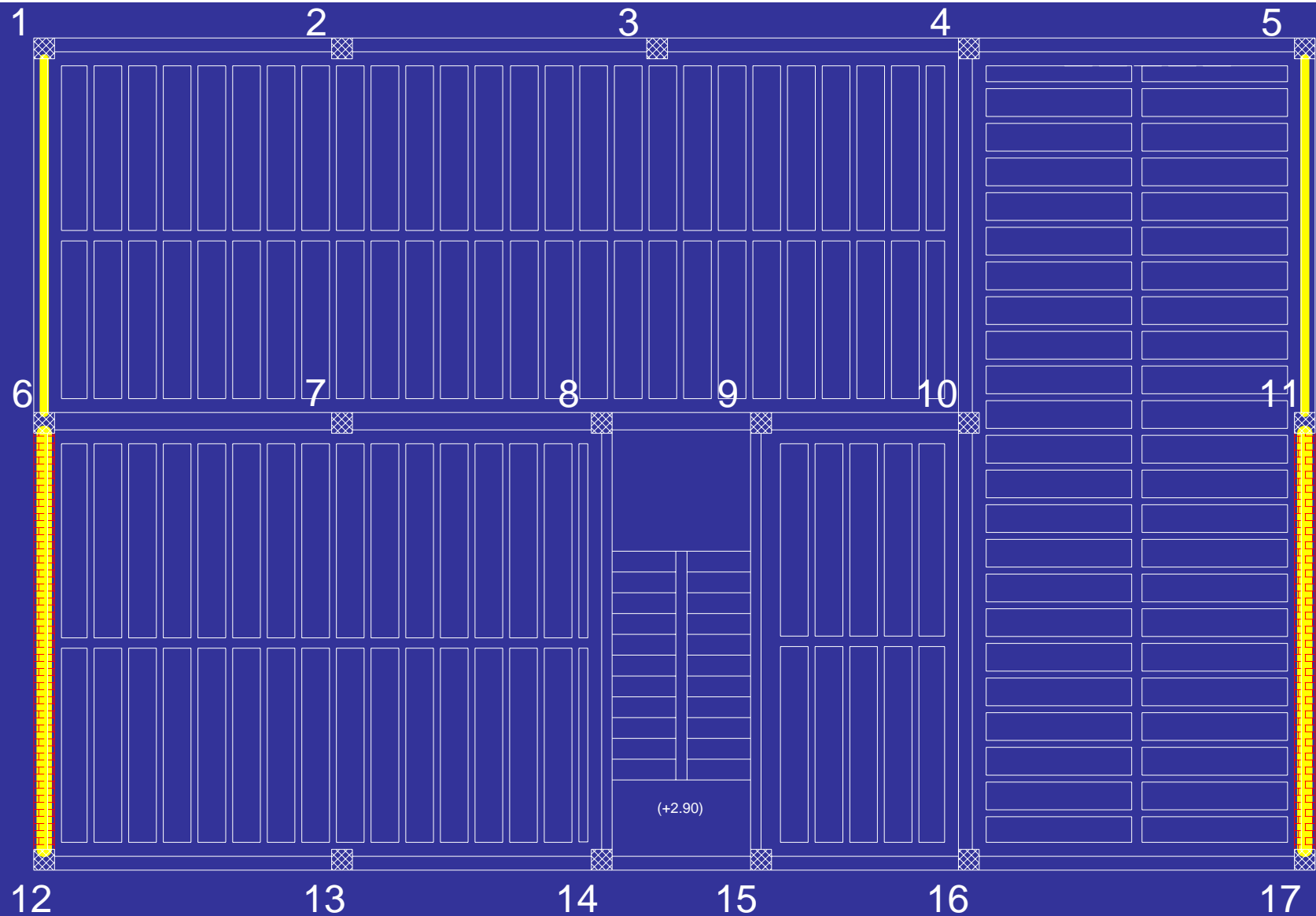


# Masonry-infilled RC building

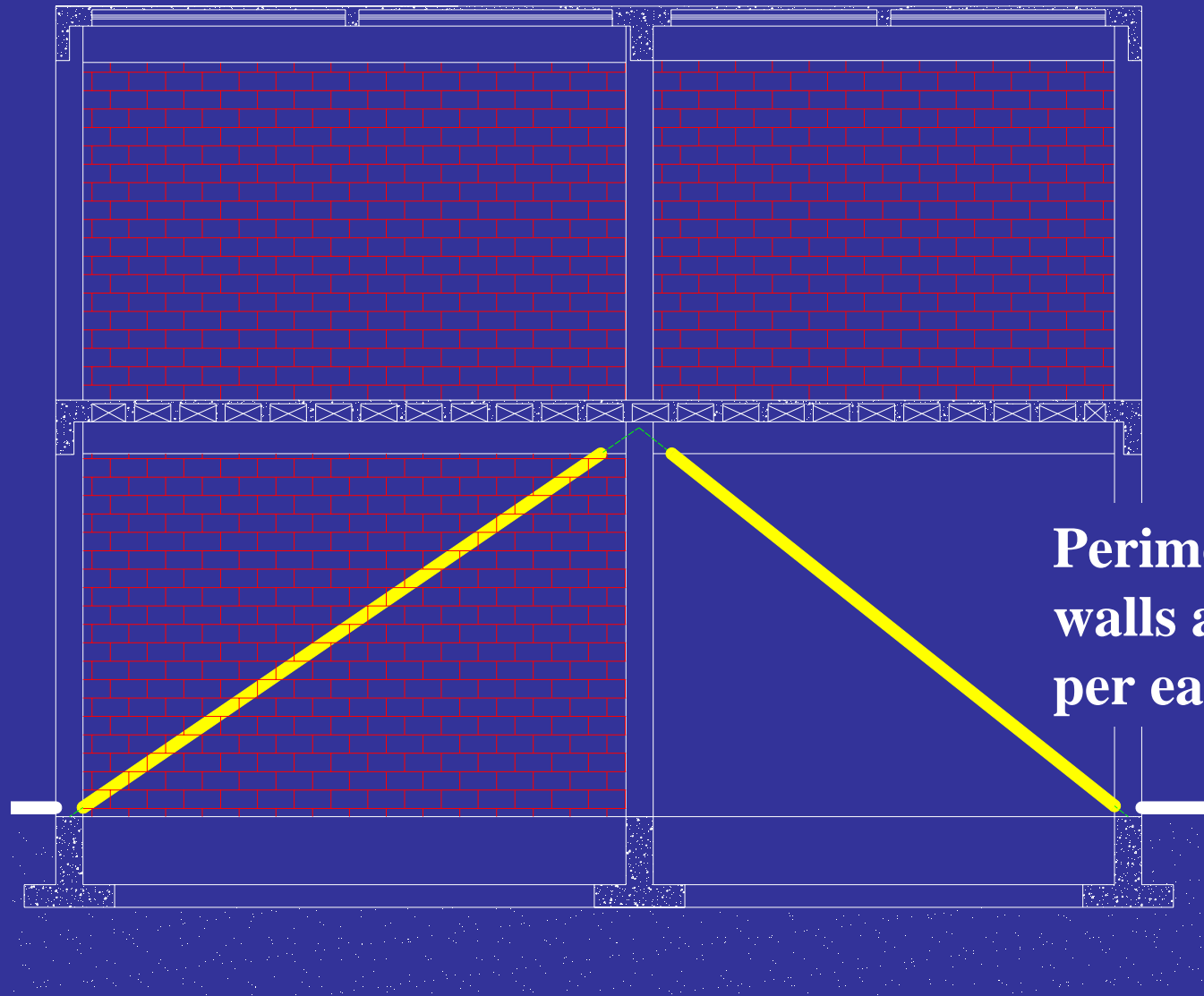
TRANSVERSE SECTION Scale 1:100



# BRBs arrangement



# BRBs arrangement



**BRBs are placed  
at 1° floor**

**Perimetric masonry infill  
walls are only in one bay  
per each building side**

# BRBs arrangement

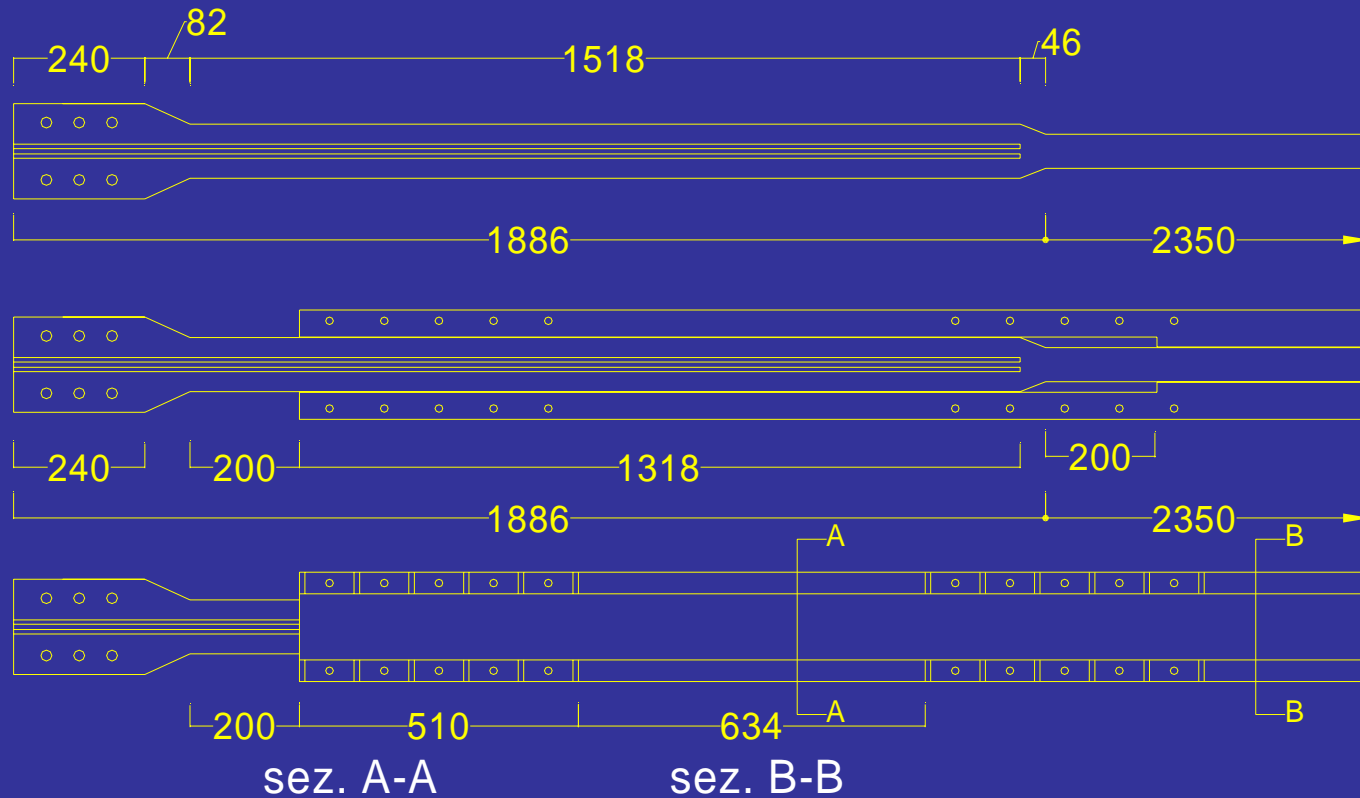
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**BRBs are hidden in the perimetric facing walls**

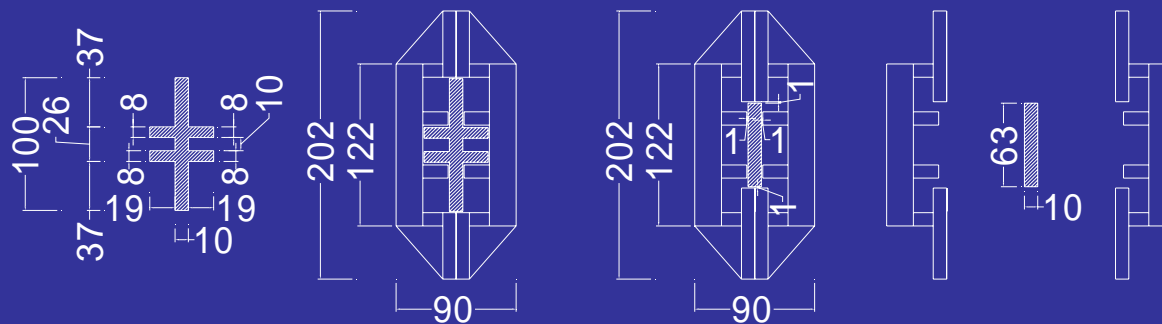


# Buckling Restrained brace to be tested



$$P_E/P_y = 2.13$$

$$L_c/L = 0.4$$

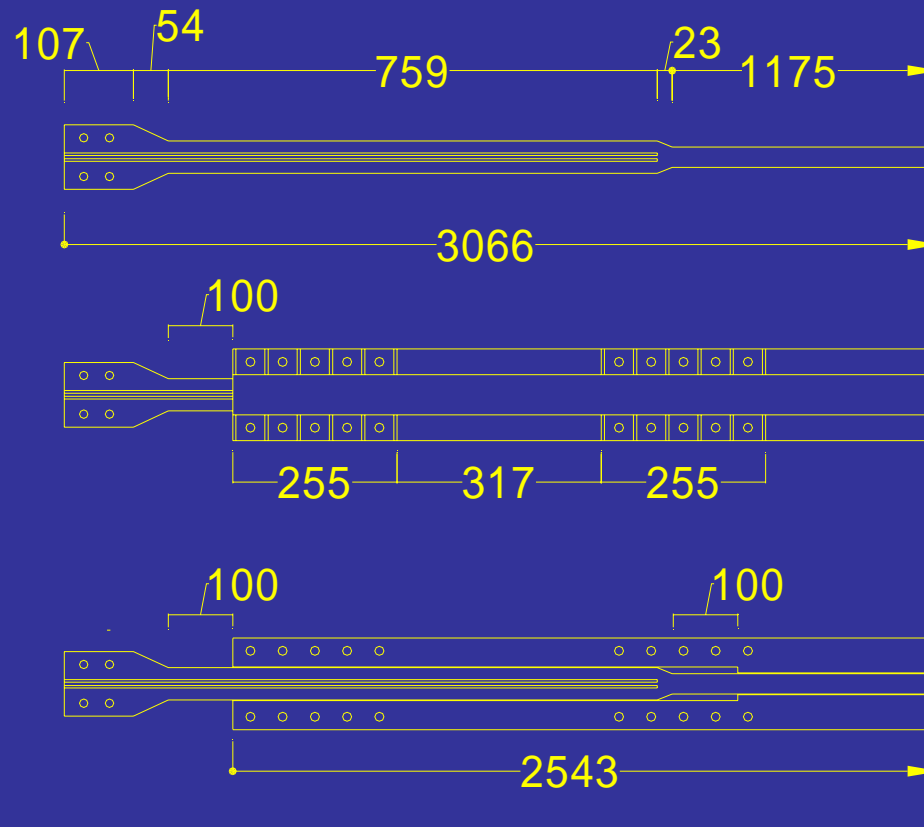


*Inner clearance:  
1mm per each side*

***Task B: Laboratory tests on  
Only-steel BRB specimens***

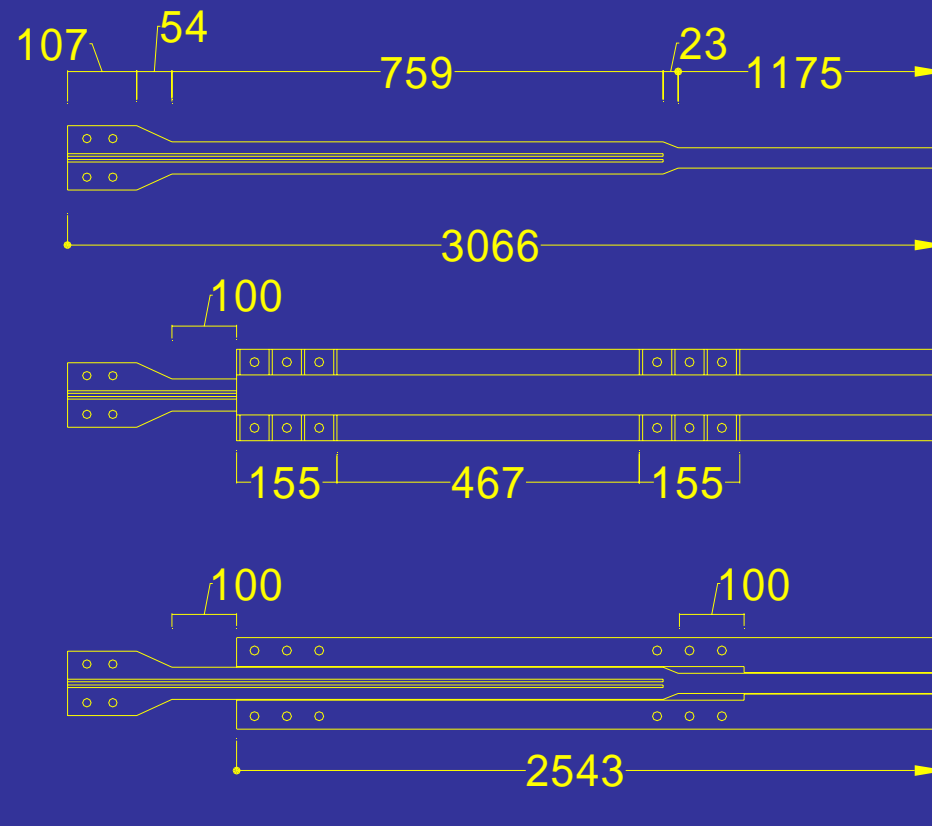
# Laboratory tests on BRB specimens

Starting from type 3, a series of BRB, realized by the same geometric method, scaled BRB specimens proportions tested in case type 3, validate this system. In particular, four sub-type P will be investigated (i.e. the same ratio  $P_E/P_y$  and the same ratio  $L_c/L$ )



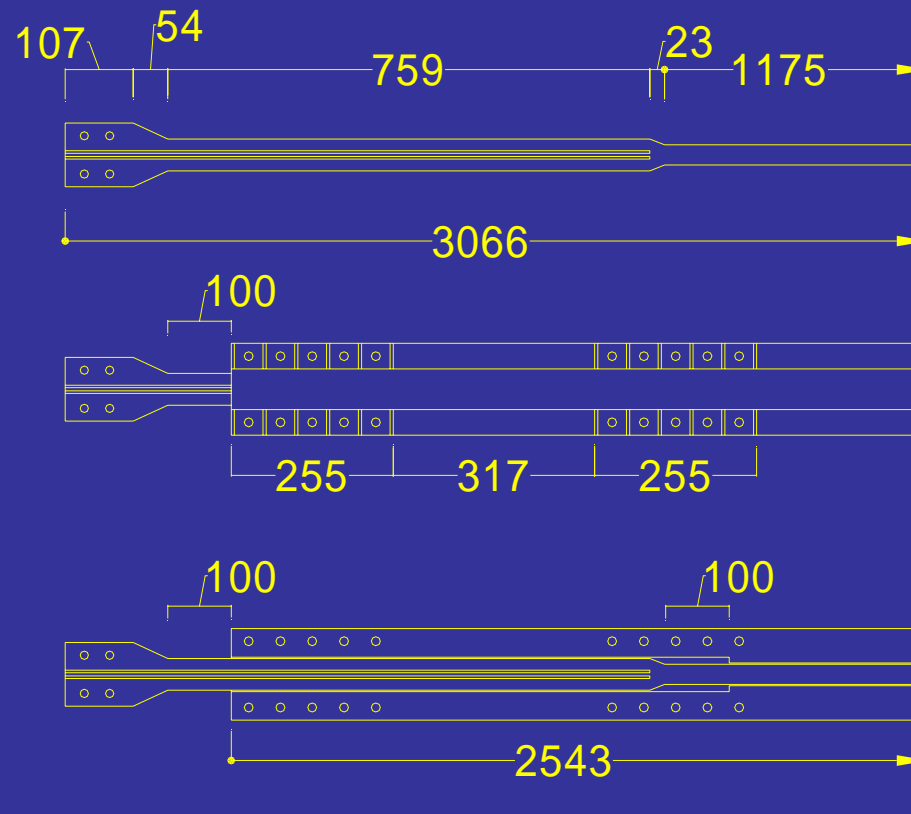
# *Laboratory tests on BRB specimens*

the sub-type 3b differs from the previous one only for the different connection resistance of the two omega profiles constituting the restraining unit



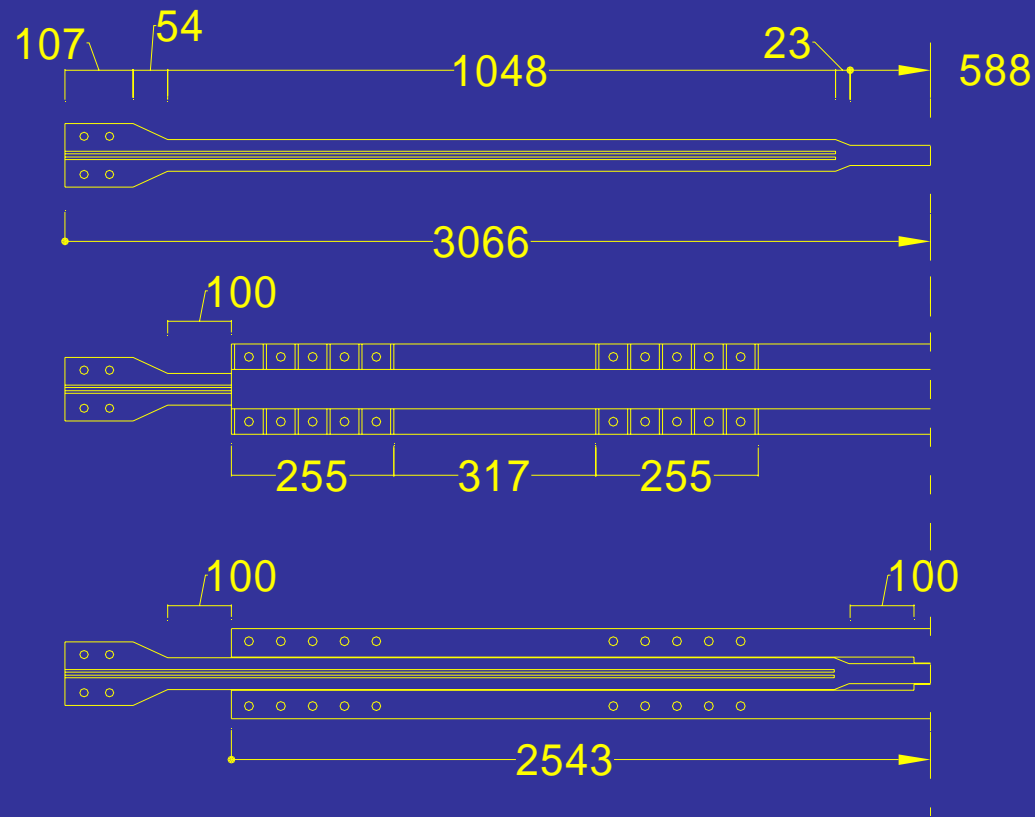
# *Laboratory tests on BRB specimens*

the sub-type 3c differs from the subtype 3a for a wider clearance between the core and the sleeve  
(from 1mm per each side to 2mm per each side)



# *Laboratory tests on BRB specimens*

the sub-type 3d differs from the first one only in the ratio  $L_c/L$  (i.e. its core length ratio is one half of the ratio for the sub-type 3a)



# *Conclusions*

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- In order to develop an innovative “only-steel” detachable BRB, an experimental campaign has been planned.
- There are two parts of the experimental program:
  - 1) full-scale tests of existing reinforced concrete (RC) structures equipped with BRBs;
  - 2) laboratory tests
- The full-scale test will be carried out to examine the response of a BRB designed to improve the seismic performance of a real two-story RC building.
- In particular, this BRB was designed to be hidden in the inner hole of facing walls.

# *Conclusions*

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- The prototypes to be studied in lab tests are scaled version of the BRB designed for the full scale test.
- These specimens will be useful to correctly design the following key aspects:
  1. inner clearance giving an understanding on how the clearance width can influence the number of higher-modes in the yielding core.
  2. the strength of sleeve connections.
  3. the strength of BRB end-connections.